ENERGY AUDIT STUDY

at

BROOKE BOND INDIA LIMITED
BANGALORE

UNDER

INDIA-EC ENERGY BUS PROGRAMME

Sponsored by

ENERGY MANAGEMENT CENTRE

(Under Deptt. of Power, Ministry of Energy, Govt. of India)
New Delhi

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May, 1991

BROOKE BOND INDIA LIMITED
BANGALORE

CONTENTS Page No.

BROOKE BOND INDIA LIMITED
WHITEFIELD FACTORY

ENERGY AUDIT REPORT

1.0 INTRODUCTION

An energy audit study was carried out by a team from TERI, to identify energy saving opportunities in the plant.

The Whitefield factory has a production capacity of 1000 MT of instant coffee per year. The main input is raw coffee seeds. The main stages of manufacturing are - roasting, granulation, extraction, evaporation, spray drying and packing.

During the study, a detailed analysis was made of the major energy consuming plant items/processes, supplemented by measurements of various energy related parameters using appropriate instruments, in order to determine their energy efficiencies and evolve suitable means to minimise wastages.

The recommendations evolved were regularly discussed with senior plant personnel to identify any practical problems that may arise in their implementation. Several suggestions were promptly implemented, immediately after discussions.

This report presents the findings, recommendations, and the financial implications of implementing these recommendations.

2.0 EXECUTIVE SUMMARY

This report details energy saving opportunities at the whitefield instant coffee plant of Brooke Bond India Limited, identified through an energy audit programme.

A. BOILER AND STEAM DISTRIBUTION:

1. The blow-down losses can be significantly reduced, by improving the feed water quality. If DM water can be used, the blow down losses could come down to less than 0.5%, resulting in a saving of about Rs.1.16 lakhs per annum.

2. There appears to be frequent clinker formation in the burner asembly which has to be cleaned in every three hours. This can be avoided by adjustment of burner assembly position and regular cleaning of burner nozzles.

3. The exhaust temperature varies between 290 °C and 335°C, which is very high. This indicates that the boiler tubes are dirty. By cleaning the boiler tubes the heat transfer efficiency would improve considerably. It is estimated that this can result in saving of fuel consumption to the extent of 4.8 percent i.e., Rs.62,000/- per annum.

4. It is necessary to regularly monitor the flue gas temperature. If the flue gas temperature is too high, then it would be necessary to clean the heat transfer surface.

5. Flue gas analysis may be done frequently, so that air/fuel ratio can be adjusted as necessary, if the combustion efficiency is low.

6. The bare lengths pipelines carrying steam and condensate, and the heat exchangers may be insulated to save heat loss and energy. Expected saving of fuel on this account would be to the extent of Rs.1.08 lakhs per annum.

7. The thermodynamic trap fitted at the outlet of steam heater is not suitable for the type of opeation and may be replaced by a float type trap. This will improve the heat transfer efficiency.

8. It is necessary to redesign the condensate receiver to handle high pressure condensate and flash steam. The receiver should also be insulated to reduce heat loss.

B. SPRAY DRYER

1. There is very good potential for recovering waste heat from the hot air exhaust by using air to air heat exchanger or heat pipes. This could save about 150 KL of HSD valued at about Rs. 8 lakhs per year.

2. The inlet temperature of the feed should be increased to 70°C as against the present 40°C, by using the hot condensate from the DM water heater. This could save 6-7 KL of HSD per year valued at Rs.43,000.

3. There appears to be considerable heat loss at the hot air generator, because of excess air supply. The combustion efficiency of 88.6 percent appears to be low for this type of heaters, and with proper tuning it can be increased to even 98 percent. Even if the efficiency can be increased to 95 percent by proper tuning, it can save about 60 KL of HSD per annum valued at Rs.3 lakhs.

4. It should be possible to increase the inlet air tempeature from 275°C to 300°C, with the existing heaters. If this can be achieved, it would result in a saving of about 60 KL of HSD valued at about Rs 3 lakhs per year

5. If there is no adverse effect on the quality of the end product, the solid content in the feed solution may be increased to 40 percent from the present 30 percent. This can give enormous savings in HSD consumption.

C. FALLING FILM EVAPORATORS

1. There would be significant savings, if a vacuum pump is used in place of steam ejector. The steam ejector requires about 100 Kg/hour of steam, whereas the cost of electricity for operating a vacuum pump would be far lower. If the same steam ejector is to be continued, then the throat of the ejector should be regularly inspected as it is subjected to constant wear and tear.

2. Steam pressure supplied to the ejector should be reduced from the present 15 Kg/cm2g to the designed pressure of 5 Kg/cm2g. This can reduce the steam requirement by as much as 70 percent.

D. AIR CONDITIONING IN THE PACKING UNIT

The bottling section and the aluminium foil packaging section may be seperated, by using partition. By operating dampers of the air system, cool air may be circulated only in the area which is being used, and not over a larger area covering both sections of packaging. This will save considerable quantity of power used in air conditioning.

TABLE - I

VARIATIONS IN SPECIFIC ENERGY CONSUMPTION OVER DIFFERENT MONTHS

Month	Quantity Elecy. Kwh	Quantity HSD Kl	Quantity Furn. oil Lit.	Cost Elecy. (Rs.)	Cost HSD (Rs.)	Cost Furn. oil (Rs.)	Total	Prodn M.T.	Avg.en. consptn. (Rs) Per Ton
Apr'89	61800	65586	31819	64170	258763	114354	437287	90.3	4842
May'89	68700	68053	33379	71541	268465	119959	459965	82.2	5595
Jun'89	65040	59871	25560	66972	236215	91860	395047	82.2	4805
Jul'89	69660	80508	31725	75857	317635	114019	507511	88.4	5741
Aug'89	73380	57451	22973	73257	226619	82565	382441	74.6	5126
Sep'89	82020	64509	31096	81810	254506	111760	448076	87.5	5120
Oct'89	73980	78016	34366	79828	307788	123511	511127	101.2	5050
Nov'89	73110	66110	24409	77467	260815	87726	426008	87.40	4874
Dec'89	80700	66137	25462	83180	260933	91510	435623	93.50	4659
Jan'90	72420	81434	39691	74058	323935	142649	540642	109.70	4928
Feb'90	71370	66054	32244	78206	261447	115885	455538	89.40	5095
Mar'90	69960	54854	26947	70956	221282	96847	389085	75.00	5187
Apr'90	64830	93470	31863	66117	460658	114516	641291	97.10	6604
May'90	64491	60725	35880	66256	286814	128953	482023	94.60	5095
Jun'90	56031	65450	30932	58087	305168	111169	474424	71.10	6672
Jul'90	65400	81205	40495	73109	371892	145568	590569	99.30	5947
Aug'90	71400	60572	29180	72392	270892	102764	446048	76.20	5853
Sep'90	62700	67650	36035	63555	307648	125520	496723	81.00	6132

3.0 ENERGY CONSUMPTION PROFILE

3.1 SOURCES OF ENERGY :

The major energy sources are Electricity, H.S.D and Furnace Oil.

The consumption of these during the 1988 - 89 year was :

	Qty	Cost (approx.)
Electricity	8,50,000 Kwh	Rs. 8.7 lacs
H S D	805 Kl	Rs. 31.8 lacs
Furnace Oil	350 Kl	Rs. 12.3 Lacs
		Rs. 52.8 lacs

However, the cost of energy would be far higher during the current year, in view of the recent steep increase in their prices.

3.2 SPECIFIC ENERGY CONSUMPTION

An analysis was carried out to relate the cost of energy consumed to quantum of production which is shown Table - 1.

The overall cost of energy per tonne of production appear to vary significantly, month to month.

3.3 MAJOR ENERGY CONSUMING PLANT ITEMS :

The major energy consuming plant items are :

All the furnace oil is used in the boilers to generate steam, for use in extraction and evaporation process :

- About 90% of HSD is used in spray dryers ; about 6% in DG sets and about 4% in roasting.

- Electricity is used in all processses - but a significant part in the fans of the spray dryer and cyclone ; airconditioning, lighting, compressors.

Bulk of the energy cost is on H.S.D,most of which is consumed in the spray dryer.

4.0 ENERGY MANAGEMENT

The total energy input to the plant was analysed and the data was related to the production for the last financial year. The specific energy consumption appear to vary significantly . The details of this is shown in the Annexure - I.

The monthly energy consumption , and the co-relation between the energy and production are dipicted in the charts shown in the various Annexures from II to V.

The share of different in forms of energy ie.,Furnace oil, Electricity and HSD is shown in Annexure VI. The quantum of consumption of various forms of energy at the major energy consuming centres is also shown in this Annexure.

Relation between Production and total energy, and Production and Electricity have been shown in Annexure VII. The chart shows, that there exist a good correlation between production and energy (total as well as electrical). Hence a detailed analysis of this data will help in monitoring and setting targets for energy consumption.

Also relationship between Production and Furnace Oil and Production and HSD have been shown in Annexure VIII. This chart shows that a good correlation exist between Production and HSD energy used.

A detailed analysis of these charts reveal that sufficient correlation exist between the total energy V/s production and also between the individual forms of energy and production. A systematic approach to energy management should easily may bring about significant savings.

5.0 BOILERS

5.1 FACILITY DESCRIPTION

There are two oil fired Nestler Boilers - one of 1.5 tons and another of 1.0 ton steam generating capacity. Only the larger capacity boiler is operated regularly on three shifts and the other is kept as standby. The requirement of steam is estimated to be about 1350 Kg/hr.

The furnace oil consumption to fire the boiler was about 343 KL last year, valued at about Rs.12 lacs.

At the time of study, only one oil fired boiler of 1.5 MT/Hr was in operation, which was taken up for indepth analysis.

The boiler is used to generate steam at 15 Kg/cmg to heat DM water at high pressure to a temperature around 180 deg. C. The average requirement of the DM water (fed to the extractors) is about 1200 Kg/Hr., at 180 deg. C.

The steam generated is also used for thermocompression in the falling film evaporators and ejector. The requirement of steam here is about 390 Kg/Hr in evaporators and about 100 Kg/Hr in the ejector.

The steam generated is at pressure of 12-15 Kg/cm, while the requirement of the falling film evaporator is just 5 Kg/cm.

There is provision for condensate recovery from the DM water heater, but not from the falling film evaporator and ejector.

5.2 ANALYSIS & RECOMMENDATIONS

A BOILER EFFICIENCY :

The detailed calculations of the boiler efficiency at maximum high fire range condition are given in ANNEXURE - IX.

It is seen that the efficiency of the boiler under high fire conditions was 72.25% and the total losses account for 27.75%. This is made up of about 18% loss in flue gases, 5.6% on account of blow down losses, 2.1% losses due to radiation and convection, and another 1.5% due to other causes.

B. AVAILABLE CAPACITY & REQUIREMENT :

The calculations in the ANNEXURE-IX show that the available capacity for generating steam at 15 Kg/sq. cm pressure is of the order of 1138 Kg/Hr, as against the average, requirement of just 850 Kg/Hr, at the same pressure.

That is, the capacity of boilers is being significantly under-utilised. It is more than adequate to meet the present demand for steam, and it may may not be necessary to replace the existing two boilers, with one 3.5 MT/hour capacity boiler.

C. COMBUSTION AND FLUE GAS ANALYSES :

The analyses of the flue gas at both high flame and low flame was carried out.

The analyses indicates that at low flame, the oxygen content was between 4.3 - 4.9%, and CO_2 content between 12.23 - 12.90% and the flue gas temperature was 295 deg. C. This shows that while the combustion efficiency is generally good, it can be further improved if the excess air could be reduced and controlled to about 18-20%. To achieve this, it may be desirable to consult the burner suppliers.

At the stage of "high flame or high firing rate", the analysis shows that the Oxygen content was between 1.9-2.2% and CO_2 content between 14 -15%, and the flue gas temperature at around 335 deg.C. The excess air was around 10%. This indicates that the combustion efficiency at high flame is generally good, and not much potential exists for further improvement.

The flue gas at under both high and low flame conditions are within acceptable limits.

D. CLINKER FORMATION

The fuel oil feed temperature to the burners is maintained at 105 deg. C, which is good. However, it was noticed that there was constant formation of heavy clinks in the burner assembly, which has to be cleaned every three hour. This is caused by the oil directly striking the burner assembly portion, which may be due to improper alignment of burner portion, and/ or due to inadequate maintenance and cleaning of the burner.

It is very necessary that the burner nozzles are checked routinely.

While it is not been possible to quantify the energy losses on these account, this situation should be avoided as it results in some heat loss. Generally, a well maintained boiler of this type should not have such problem.

E. RADIATION AND CONVECTION LOSSES :

The radiation and convection losses, is a constant factor not related to the boiler output. This loss of 2.1% at high flame and 5.13% on low flame appear to be within acceptable limits.

F. BLOW DOWN LOSSES :

The present blow down losses as calculated appears to be very high. This is now at 13.54% on low flame and 5.55% on high flame.

A normal package boiler should not have a blow down loss of more than 3% in terms of feed water.

An analysis of blow down condensate sample indicates a TDS content of 5950 ppm which is very high. This should not exceed 3000 ppm for a package boiler. It was also seen that silica content present as SiO_2 was about 45 ppm, while should be nil.

It is very essential that the feed water quality is considerably improved. If it is possible to use DM water, the blow down losses could be almost nil. This would result in a saving of oil to the extent of 9 percent ie., Rs. 1.16 lakhs per annum.

G. CLEANING OF BOILER TUBES

The flue gas exhaust temperature varies between 290°C and 335°C, at low flame and high flame, which is very high. Such high temperature indicates that the heat transfer efficiency of boiler tubes is inefficient, which is normally due to Boiler tubes being dirty.

The heat transfer efficiency would increase considerably, if the boiler tubes are regularly cleaned. If the boiler tubes are free from dirt and hat transfer efficiency normal then the exhaust gas temperature should not be more than 240 deg.C.

It is necessary that this temperature is measured on a regular basis, and boiler tubes infected and cleaned whenever the temperature is more than 240 deg.C.

This would improve the efficiency of the boiler considerably. On a rough estimate, this could result in reduction of fuel consumption by atleast 4 percent or a saving of about Rs.60,000 per annum.

H. MONITORING FLUE GAS TEMPERATURE

It is necessary that the flue gas temperature is constantly monitored, both at low fire and high fire stages. This should not be difficult as there is a thermocouple point. Such monitoring will show if the heat transfer area is effective or dirty. Every 15 deg. C rise in flue gas temperature, means there is 1% extra fuel consumption.

I. MONITORING OF COMBUSTION EFFICIENCY :

It is necessary to carryout flue gas analysis atleast once a week, to check combustion efficiency and air / fuel ratio settings. This will enable taking corrective steps immediately.

J. LOW FLAME

It is understood that most of the time, the boiler operates on low flame, because the steam demand peaks only when the falling film evaporator is working.

It is suggested that the burner turn down ratio be lowered, so that the boiler operates at higher efficiency most of time.

The various recommendations made above if implemented could considerably reduce furnace oil consumption.

6.0 STEAM UTILISATION

Steam obtained from one of the boilers. The steam generated is used to heat DM water and for the concentration of dicoction in the falling film evaporator. The steam used in evaporators account for 60% or about 210 KL of furnace oil. The remaining is used for heating DM water used in the extractors.

A. The high pressure steam generated by the boilers is distributed between the two stages heat exchanger and the falling film evaporator.

It was observed that the steam piping line towards the falling film evaporator - of a length of 6 meters of 50 mm dia. with an inside pressure of 15 kg/sq.smg. is not insulated.

It was also observed that the pipe I line - of length of about 20 meters of dia 25 mm carrying condensate at 90 deg.C was not insulated. (It was explained that this was not done to avoid steam flashing in the condensate recovery tank).

It was also noticed that the two stage heat exchangers were also not insulated.

Surface temperature measurements and calculations made show, that the heat energy lost due to convection and radiation due uninsulated surfaces as above including the condensate tank, would be about 8900 K.cal /hour, which can be saved by proper insulation.

B. DM water used for extraction is heated in a two stage heat exchange system . DM water enters the first stage heat exchanger at a temperature of 30 deg.C and is heated to 80 deg. C, by means of the condensate coming from the second stage heater at a tempeature of 101 deg.C.

The DM water at 80 deg. C from the first stage heater enters the second stage heater, where its temperature is rised to 180 deg.C by using the high pressure steam (15 Kg.cm2g) coming from the boiler. This condensate is fed to the first stage heat exchanger.

C. It was noticed that the trap fitted at the outlet of this steam heater was of thermodynamic type. The trap was not working and a by-pass valve was being used to control the condensate outlet. This system will not be efficient , and since both steam and condensate will flow through the valve, the heat transfer efficiency is bound to be low.

Thermodynamic traps are not suitable for this kind of continuous operation and generally used for intermittent outlet, and the discharge temperature most of the time will be less than the saturated steam temperature. The trap will open only when the steam pressure above the disc drop due to condensation.

It is suggested, this may be replaced by a float trap. Float trap discharges condensate continuously at steam temperature and work equally well both on heavy and light loads. This is particularly suited for the heaters and heat exchangers used, which require immediate removal of condensate as soon as they are formed.

D. The first stage heat exchanger has no trap at the outlet. The inlet temperature of the condensate indicate that the pressure is around 1.2 Kg/cm2g. The condensate outlet is around 90 deg. C which indicates that flashing has occured and the condensate is raised to about 4.5 m above ground level by the pressure and discharged into the condensate tank.

If this system is to be utilised, it is suggested that another trap at the outlet of the heat exchanger be installed, to ensure complete utilisation of heat.

However, it may be more effective to install a simple heat exchanger, so that the condensate temperature is just around 50- 60 deg.C to ensure that the most of the heat is extracted from the steam and the condensate. Alternatively, a two stage heat exchanger, may be installed with temperature approaches close enough to achieve maximum heat transfer with an outlet temperatures of 50 to 60 deg. C.This will require two traps, one at each end. The first trap will be a float trap and second of thermostatic (or a liquid expansion trap) which letout condensate at 70 deg.C.

E. The material and energy calculations show that the steam requirements for DM water heating should be around 240 Kg/hour, where as the actual steam used is around 317 Kg/hour.

It should be possible to design a heat exchanger with heat transfer rates as high as 97%. If this is done, there would be a saving of about 77 Kg/hour steam ie.,about 30% saving in energy consumption.

F. The present condensate tank is a rectangular MS uninsulated tank, with an opening at the top for steam venting, condensate return and feed water. It is now suggested to have a condensate drain with insulation and a vent with a relief valve for safety.

7.0 SPRAY DRYER

7.1 GENERAL VIEW

This is the final stage before packing in the production of instant power coffee.

The liquor from the extractors is collected in two separate vessels. The first half of the liquor is strong in concentration about 25% and the second half of the liquor processed through the extractors is around 18% concentration. Since this is a semi batch process, each time extraction is exhausted, a new one is taken on line after filling with granulated coffee seeds. The first half hour output from the battery of extractors is concentrated liquor and the second half is of low concentration. The high concentration liquor is further concentrated upto 30% addition of rework got from the cyclones and the spray dryer. This concentrated liquor is then transferred to a storage vessel from where it is fed to the spray dryer through a high pressure pump.

The lean liquor is concentrated in the falling film evaporators from around 18% to 30% . This too is transferred to the storage vessel from where it is fed to the spray dryer.

The production rate of spray dryer is designed for 180 Kg/Hour of coffee powder.

The main energy consuming equipment in this process is the hot air generator, which supplies hot air to the spray dryer. Most of the HSD consumption by the factory, i.e., as much as 90% is used by this hot air generator. Last year, the consumption of HSD by the factory was about 805 Kl, of which only 46 Kl was used by the DG sets to generate electricity, and a small part in roasting, while the remaining about 700 Kl was used in the hot air generator. The value of HSD used by the factory was to the tune of Rs.32 lacs.

7.2 ANALYSES AND RECOMMENDATIONS:

A detailed analysis was also made of the process particularly with regard to identifying energy saving opportunities, which are discussed.

A detailed analyses of ` Material and Energy Balances´ and ` Evaporative Efficiency´ in respect of Spray Dryer was made, which is shown in Annexure X and XI.

A. RECUPERATION OR PARTIAL RE-CYCLING OF HOT EXHAUST AIR:

There appears to be significant potential for recovering waste heat from the hot air exhaust.

The measurements of the exhaust from the spray dryer at the stack outlet indicate that its temperature is about 105 deg.C and RH 5%.

Two viable alternatives are available for recovering heat from this escaping hot air.

First alternative using Recuperators:

Two possibilities exist of either using (i) air to air heat exchangers, or (ii) using heat pipes, for recovering waste heat.

Heat transfer efficiency upto 70% can be achieved by using the heat exchangers, and upto 80% using heat pipes.

Measurements show that while the temperature at the stack outlet was 105 deg.C, the surface temperature at the top portion of the stack was 78 deg.C. By insulating the entire stack and the cyclones, the exit air temperature could rise further. The temperatures of the air coming out of the spray dryer before going to the cyclone is around 120 deg.C.

It is suggested that - either air to air heat exchangers or heat pipes be installed in the exhaust stack, with proper insulation to the outlet pipes. The air from this can be piped into the spray drier mixed with that generated by the hot air generator. The exact mix ratio of recouped hot air and that produced by the hot air generator needs to be determined and regulated.

It is estimated, that a temperature of about 90 deg.C for the recouped air is easily achievable, which can save considerable HSD fuel used by the hot air generator. On a conservative estimate, the consumption of HSD can come down by 20% ie., a saving of about - 150 Kl of HSD valued at Rs.8 - 9 lacs (at current prices), in a year.

However, since the exhaust air from the stacks contain some amount of fine coffee particles which will to some extent cling on to the heat exchanger fins, which can reduce the heat transfer efficiency of the heat exchangers, periodic cleaning of the fins would be necessary. This may be done once a day using a hot water jet during coffee break.

Second alternative : Recycling the hot exhaust air:

While the first alternative, though requires some investment on heat exchanger / heat pipes is preferable, the other alternative would be to recycle the hot air directly into the spray dryer mixing in suitable ratio with the air from the hot air generator.

The quantum of exhaust air to be mixed will keep varying depending on the seasonal ambient temperature, and will have to be regulated.

However, a small quantity of fine coffee particles in the exhaust hot air will be at a higher temperature than the exhaust air recycled, and it should be considered if this slight unevenness in the heat exposure would have any adverse effect on the product.

The extent of savings that could be derived in terms of energy savings would be also around 20%. That is, there could be a saving of about 150 Kl of HSD, valued at Rs.8-9 lacs. (Under current prices) per year.

B RETENTION OF HEAT IN FEED INLET :

It is obvious, if the coffee solution feed temperature is higher, less heat is required to spray dry it.

It is calculated that if the temperature of the feed is retained at 70 deg.C instead of the present 40 deg.C, the heat requirement inthe spray dryer would come down by 4 percent. Preheating of the feed will also reduce feed viscosities and result in improved atomization. This increase in feed temperature can be achieved by the waste heat recovered either from the blowdown or from the condesate recovery system. This will result in a saving of about one litre/ of HSD amounting to Rs.43,200/- per annum.

C. COMBUSTION EFFICIENCY FOR HOT AIR GENERATOR ;

Detailed analysis of flue gas from the hot air generator was carried out . The system design indicates that just 5% air is required for complete combustion.

However, the analysis indicates that the excess air was to the extent of 100%, which shows that there is considerable heat loss. This was so, even when the fresh air dampers were kept closed.

The HSD flow rate, when manually measured, was about 80 litres per hour under normal working. Under this condition, the calculated heat released by its combustion should be around 7,52,000 K.cal/hour at 100% combustion efficiency.

Normally, in heaters of the type used, the combustion efficiency should be as high as 98% ie., the heat released for the existing HSD flow rate should be 7,36,960 K.cal/Hour.

The actual measurements of air flow was 11,422 Kg./hour atat a temperature of 267 deg.C, ie., heat equivalent of 6,49,685 - K.cal/hour. The temperature attained for the heat generated at 98% combustion efficiency, for the rate of air flow should have been 295 deg.C, whereas it was only 267 deg.C.

This shows that the combustion efficiency is around 88.6%. It is suggested to properly tune the firing system by analysis of the flue gas. If the efficiency could be raised by 8% from the present 88%, the savings on this account would be about 60 Kl of HSD or Rs.3.0 lacs per year.

D. INCREASING AIR INLET TEMPERATURE ;

At present the air inlet tempeature is to be maintained at 275 deg.C, though measurements show that it was around 267 deg.C.

Considering the heat capacity of the heaters, it should be possible to increase the inlet air temperature to 300 deg.C with a very little extra fuel consumption.

If this is achieved, and if the increase in the air inlet temperature to 300 deg.C does not have any adverse effect on the quality of the product, then such a step will increase the spray dryer capacity by about 10 % .

It may be examined if the increase air inlet temperature to spray dryer would adversly affect the quality of the product.

E. INCREASING SOLID CONTENT IN THE FEED :

At present, the solid content in the feed solution is maintained at 30%.

Increasing this solid content would not only increase the capacity of the spray dryer., but also would reduce the energy consumption significantly. This is because the heat required to evaporate a given quantity of water is virtually the same irrespective of product output and thus there is a significant increase in product output will increase in feed. Solids for a given evaporation capacity.

It is calculated that, if the solid content in the feed is increased from the present 30% to 40%, the heat energy required to spray dry would get reduced by as much as 36%, which can give enormous savings in HSD consumption. Besides, the output capacity of the spray dryer would significantly increase.

However, this should be examined from the point of its effect on the quality of the product. If increase of solids in the feed does not adversly affect the quality of the product, this proposal is worth exploring.

F. **HOUSEKKEEPING ;**

It was observed that the supply of air to the bottom conical portion of spray dryer for cooling the spray dryed coffee was not being de-humidified, because the chilling plant was not in operation. With the result the unit was sucking air through its various leakage points.

This may be immediatly attended to improve the overall efficiency of the dryer.

8.0 FALLING FILM EVAPORATOR

8.1 The lean liquor coming from the evaporations to be further concentrated to around 30% is fed to the falling film evaporator. Steam at 5Kg/cm2g is supplied to the ejector for the creation of vacuum for thermo compression and evaporation. Vacuum can also be created by the vacuum pump driven by a motor.

8.2 The energy considerations for the falling film evaporator are the steam and vacuum pump. The steam is supplied to the evaporator at 15 Kg/cm2g instead of the design pressure of 5 Kg/cm2. High pressure can result in vary consumpion in the ejector, as higher the up stream pressure for a given cross section, the flow rate would increase, based on the application of Bernoulli's theorm the increase in flow rate would be around 70%. Hence it is advisable to reduce the pressure to 5 Kg/cm2g, which is the design pressure so that the consumption of steam is around the design pressure requirement of 100Kg/h.

8.3 Steam ejectors are prone to errosion at the throat, over a period of time. Regular inspection in this respect should be carried out as increased orifice diameter is likely to increase the steam consumption, which is directly proportional to the velocity.

It is very much likely that the present steam consumption at the ejector is much higher than the required quality of 100Kg/h. because of the reasons mentioned above.

8.4 REVERSE OSMOSIS ;

Evaporation is an energy intensive process. The low concentration liquor is presented concentrated by using a falling film evaporatoion from around 18% to 30%. Steam required for the process is got from the boilers generated byusing fuel oil.
The availability of furnace oil is getting to be difficult and more expensive.

It may be of interest to explore alternative methods , which are less depended on it.

One of the alternatives that may possibly find application which can be further explored is the reverse osmosis process.

Osmosis is a phenomenon in which solvent transfer takes place across a membrane due to porous structure of the membrane. Reverse Osmosis is a process where if a pressure greater than the osmatic pressure is applied across the membrane , the flow of solvent is reversed.

This process does not use any heat energy, but a high pressure pump would be require to drive the solvent molecules through the membrane. The whole process of extraction takes place at room temperature.

Such processes are now being manufactured in the country.

However it will need a very detailed study by the company to evaluate the suitability of its application in the plant.

9.0 AIR CONDITIONING

The Air conditioning unit supplies the conditioned air to the packaging section. The packing room has two sections, with facilities to pack coffee in Aluminium foil and in Glass bottles. The section mostly used in the Aluminium foil packing section which occupies about 30% of the total floor area, and the rest 70% is sparely used. It is suggested that these two sections be separated by a partition and the dampers at the air ducts be kept closed/ or the section which is not in use. This will being down the cooling load considerably and thus reduction in power consumption.

10.0 ACKNOWLEDGEMENT

We are extreamly grateful to the Management and Staff of M/s Brooke Bond India Ltd, for the kind co-operation given to us for carrying out the study and in providing all the relevant information. We are thankful to Mr Praful Patel, Factory Manager for sparing their time in taking us around the plant and explaining the process.

ANNEXURE - I

TATA ENERGY RESEARCH INSTITUTE, BANGALORE

BROOKE BOND INDIA LIMITED, BANGALORE

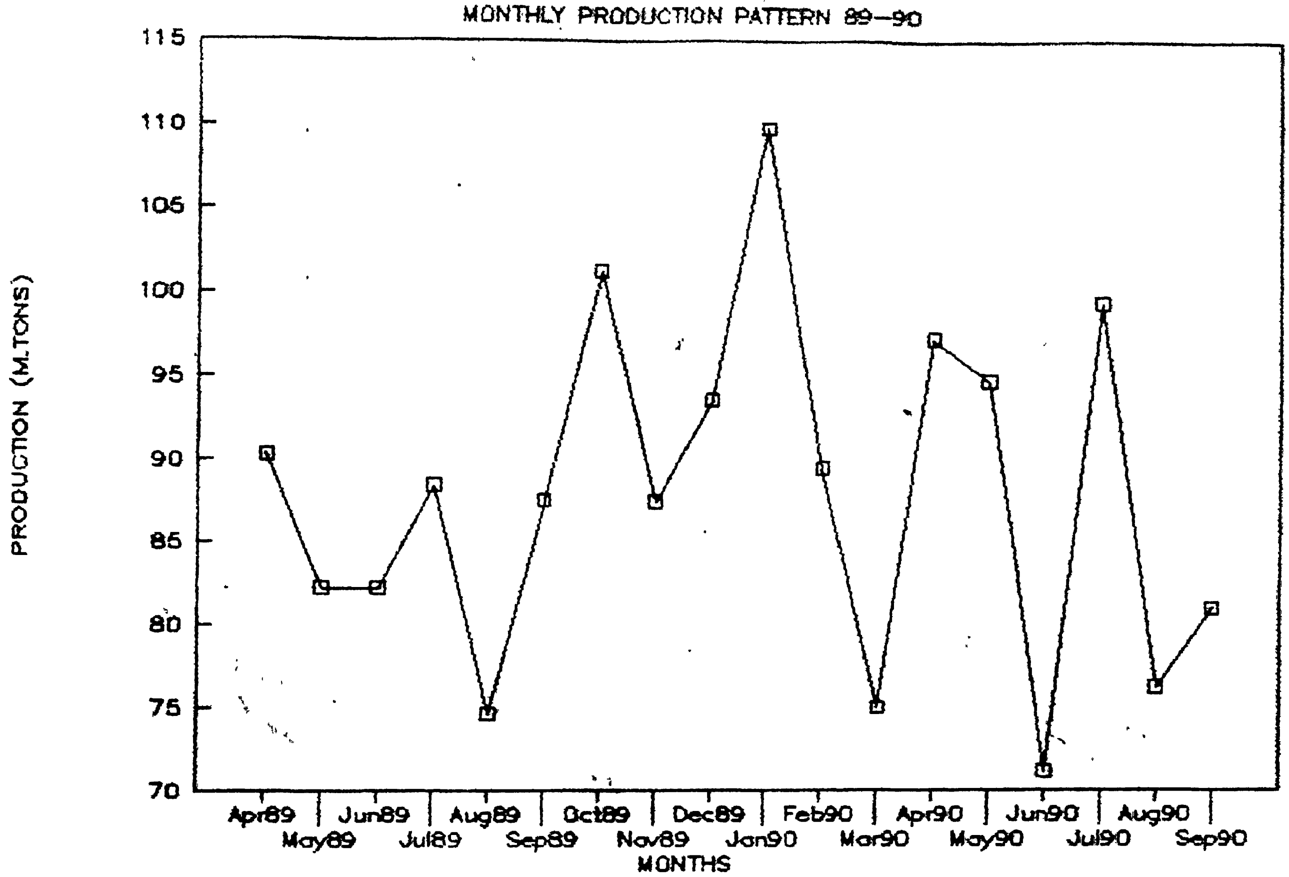
ENERGY AUDIT STUDY

MONTH	QUANTITY: ELECTRICITY	QUANTITY: HSD	QUANTITY: F.OIL	TOTAL ENERGY	COST: ELECTRICITY	COST: HSD	COST: F.OIL	COST: TOTAL	PRODUCTION	SP.ENERGY COST	SP.ENERGY CONSUMPTION
	kWh	lit	lit	G.Cal	Rs	Rs	Rs	Rs	M.T	Rs/m.Ton	G.CAL/M.TON
Apr89	61800	65586	31819	1027	64170	258763	114354	437287	90	4843	11
May89	68700	68053	33379	1073	71541	268465	119959	459965	82	5596	13
Jun89	65040	59871	25560	910	66972	256215	91860	415047	82	5049	11
Jul89	69660	80580	31725	1183	75857	317635	114019	507511	88	5741	13
Aug89	73380	57451	22973	867	73257	226619	82565	382441	75	5127	12
Sep89	82020	64509	31096	1027	81810	254506	111760	448076	88	5121	12
Oct89	73980	78016	34366	1187	79828	307788	123511	511127	101	5051	12
Nov89	73110	66110	24409	968	77467	260815	87726	426008	87	4874	11
Dec89	80700	66137	25462	985	83180	260933	91510	435623	94	4659	11
Jan90	72420	81434	39691	1274	74058	323935	142649	540642	110	4928	12
Feb90	71370	66054	32244	1044	78206	261447	115885	455538	89	5096	12
Mar90	69960	54854	26947	878	70956	221282	96847	389085	75	5188	12

ANNEXURE - II

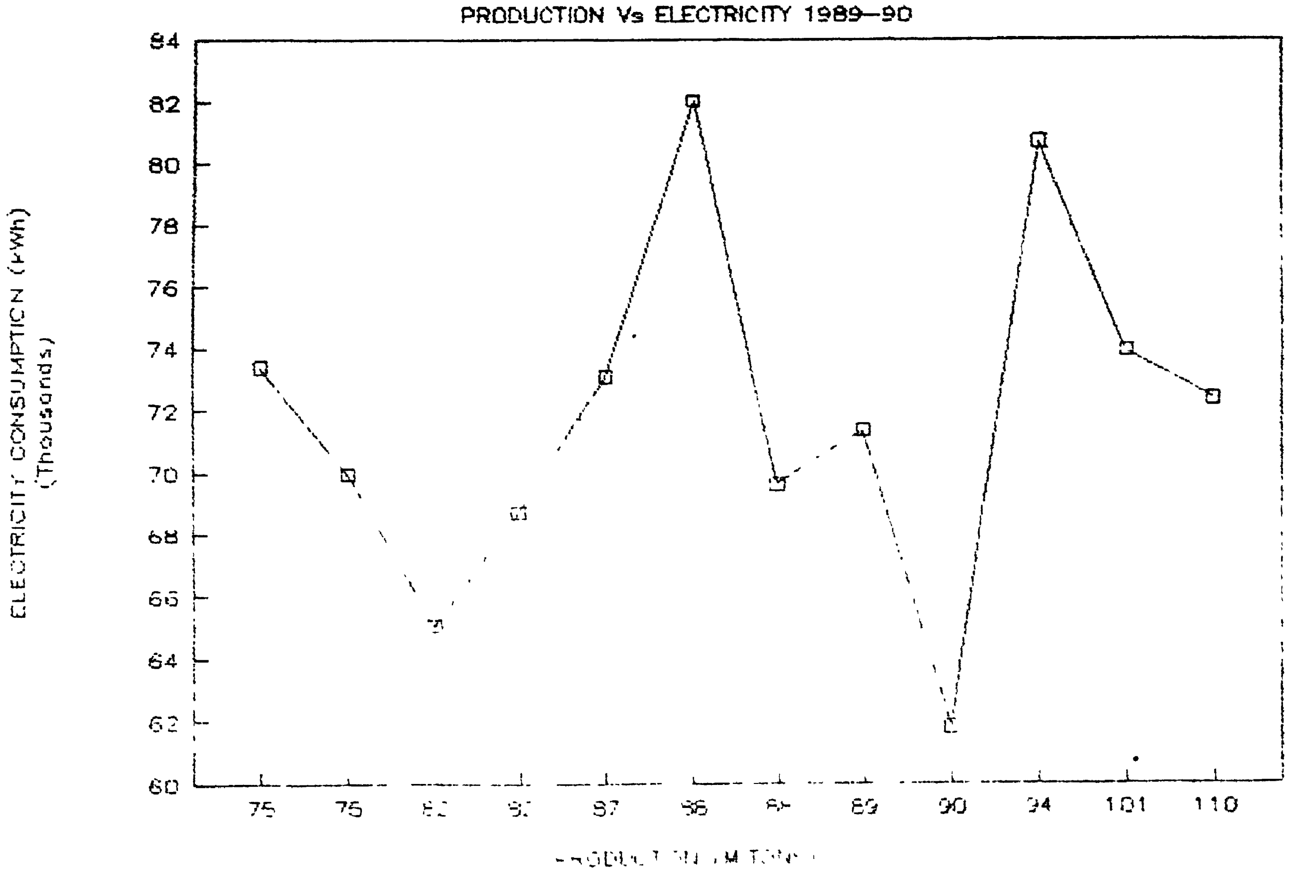
BROOKEBOND INDIA LIMITED

MONTHLY PRODUCTION PATTERN 89–90



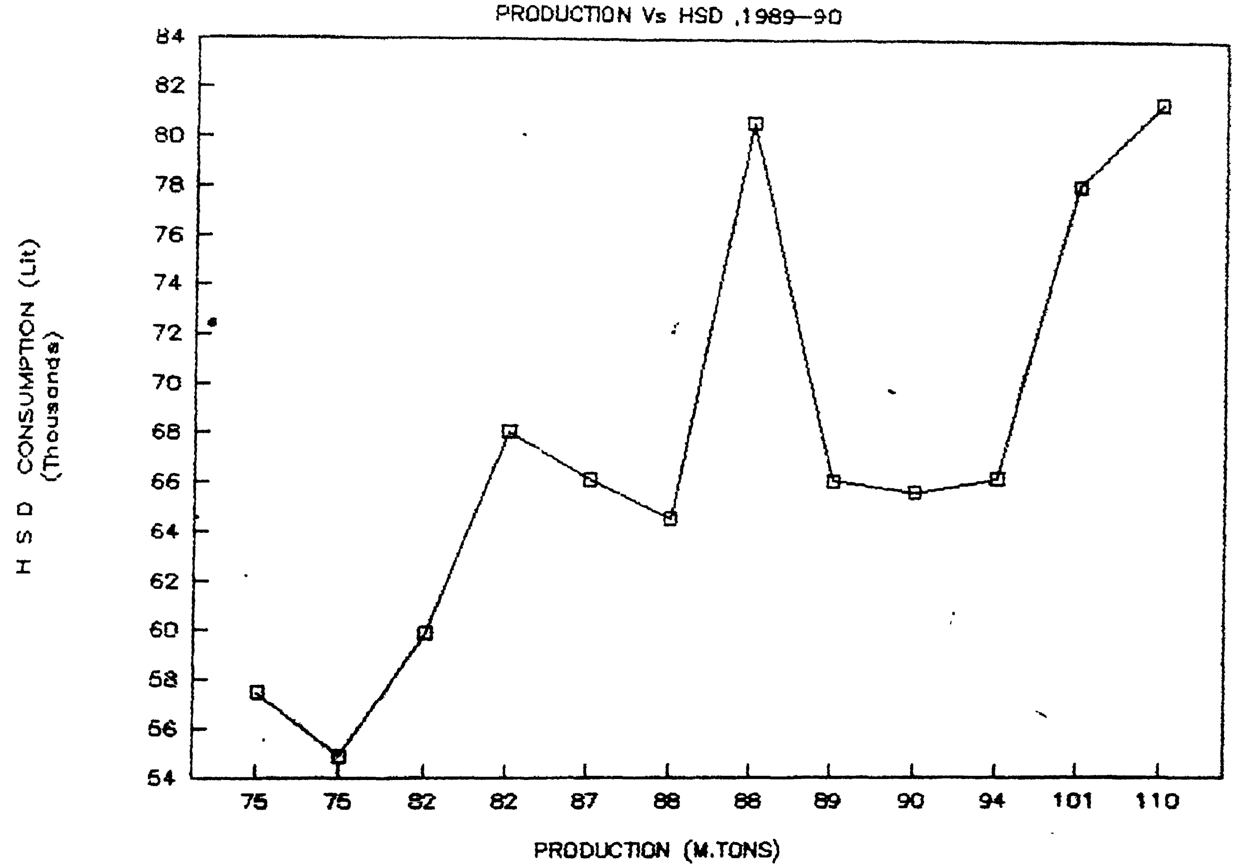
BROOKE BOND INDIA LIMITED

PRODUCTION Vs ELECTRICITY 1989–90



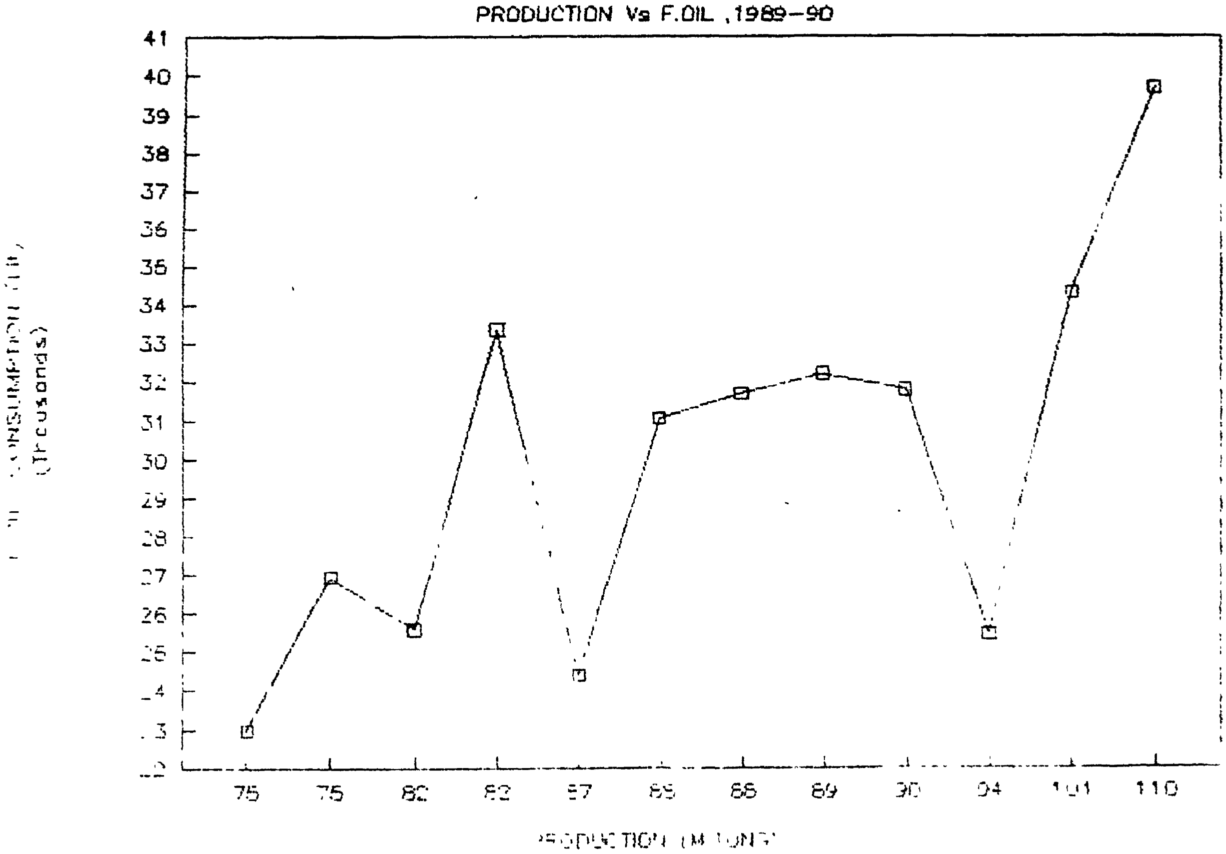
BROOKE BOND INDIA LIMITED

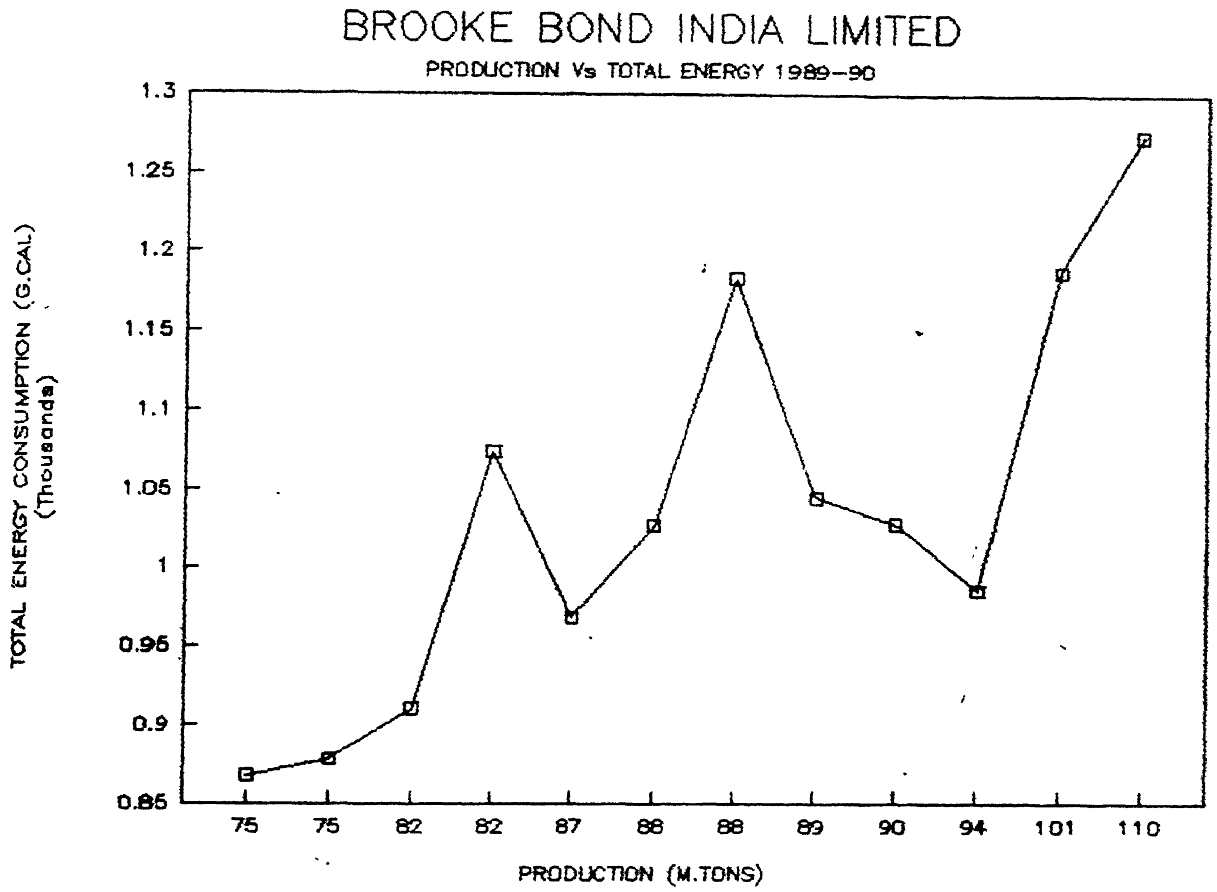
PRODUCTION Vs HSD ,1989-90

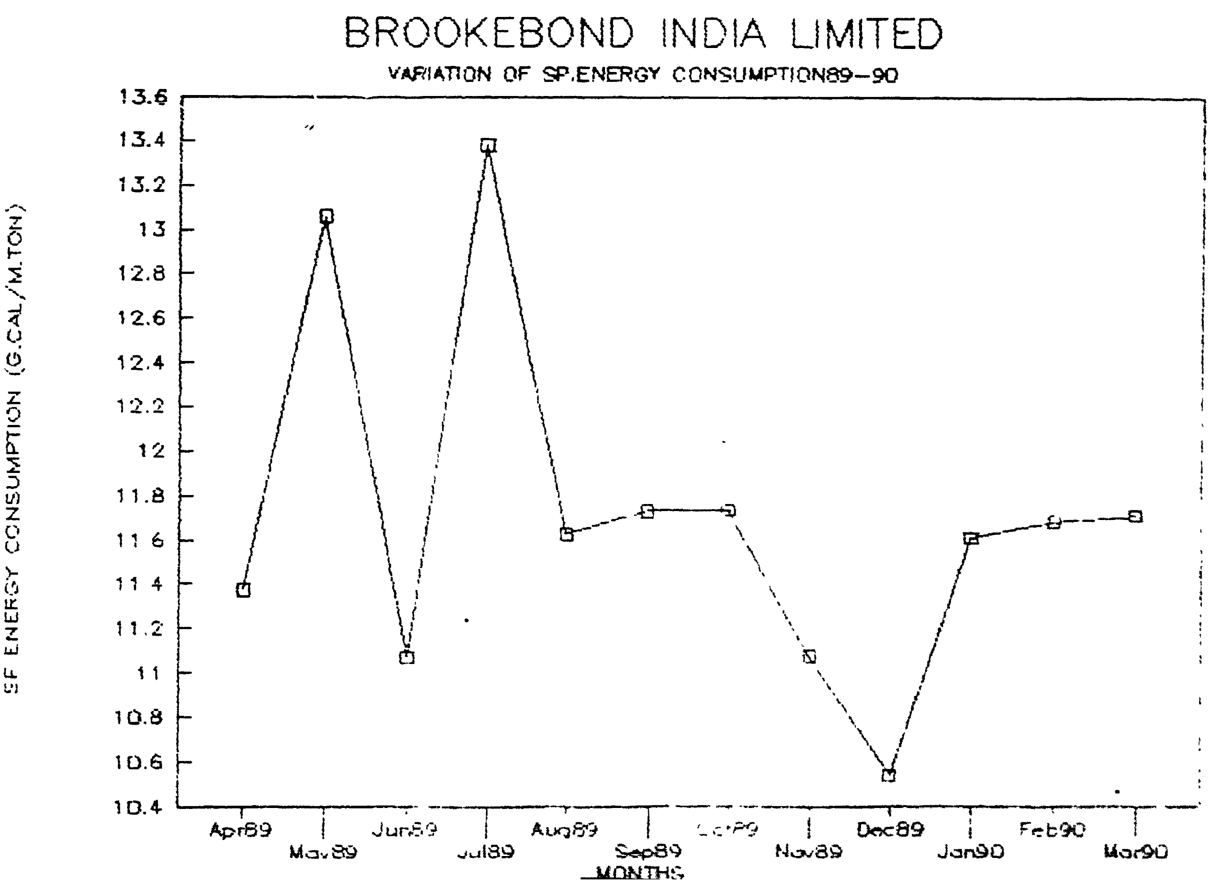


BROOKE BOND INDIA LIMITED

PRODUCTION Vs F.OIL ,1989-90

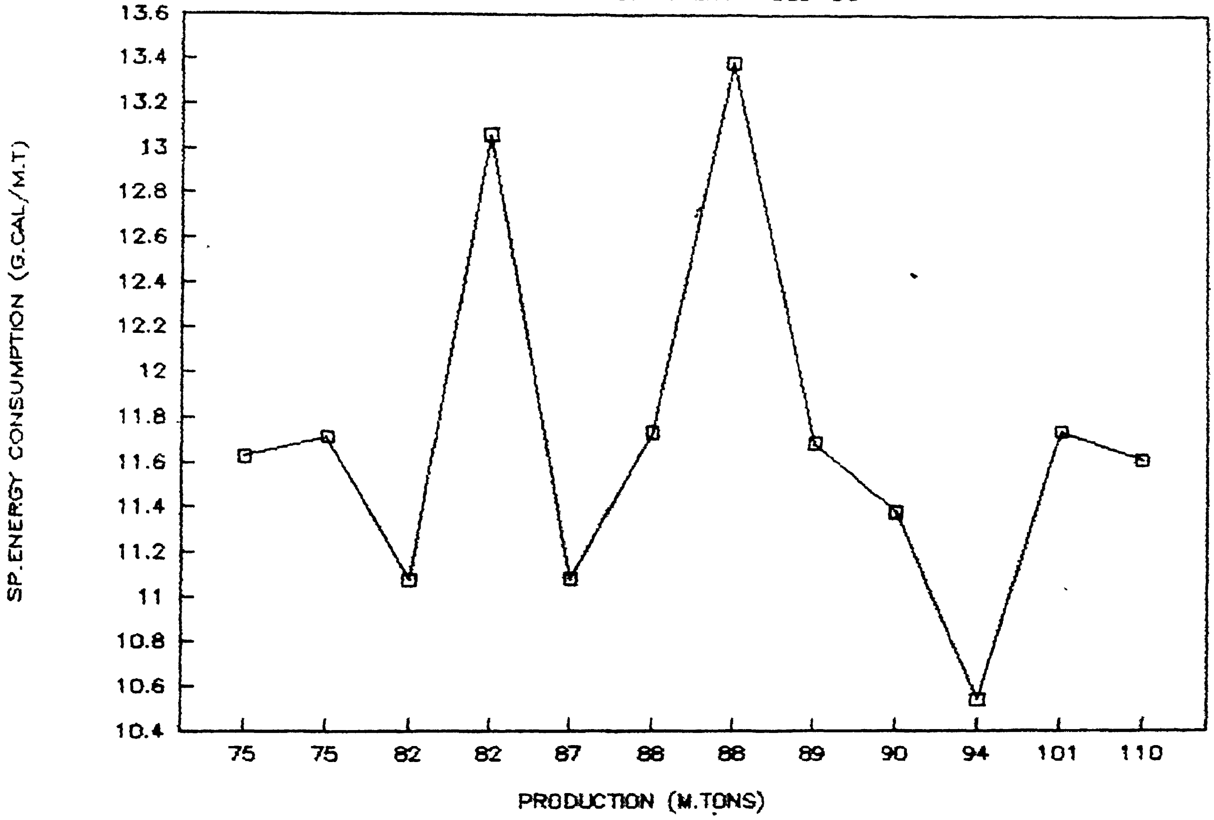



BROOKE BOND INDIA LIMITED
PRODUCTION Vs TOTAL ENERGY 1989-90
TOTAL ENERGY CONSUMPTION (G.CAL) (Thousands)
1.3
1.25
1.2
1.15
1.1
1.05
1
0.95
0.9
0.85
75
75
82
82
87
88
88
89
90
94
101
110
PRODUCTION (M.TONS)


BROOKEBOND INDIA LIMITED
VARIATION OF SP.ENERGY CONSUMPTION89-90
SP ENERGY CONSUMPTION (G.CAL/M.TON)
13.6
13.4
13.2
13
12.8
12.6
12.4
12.2
12
11.8
11.6
11.4
11.2
11
10.8
10.6
10.4
Apr89
May89
Jun89
Jul89
Aug89
Sep89
Nov89
Dec89
Jan90
Feb90
Mar90
MONTHS

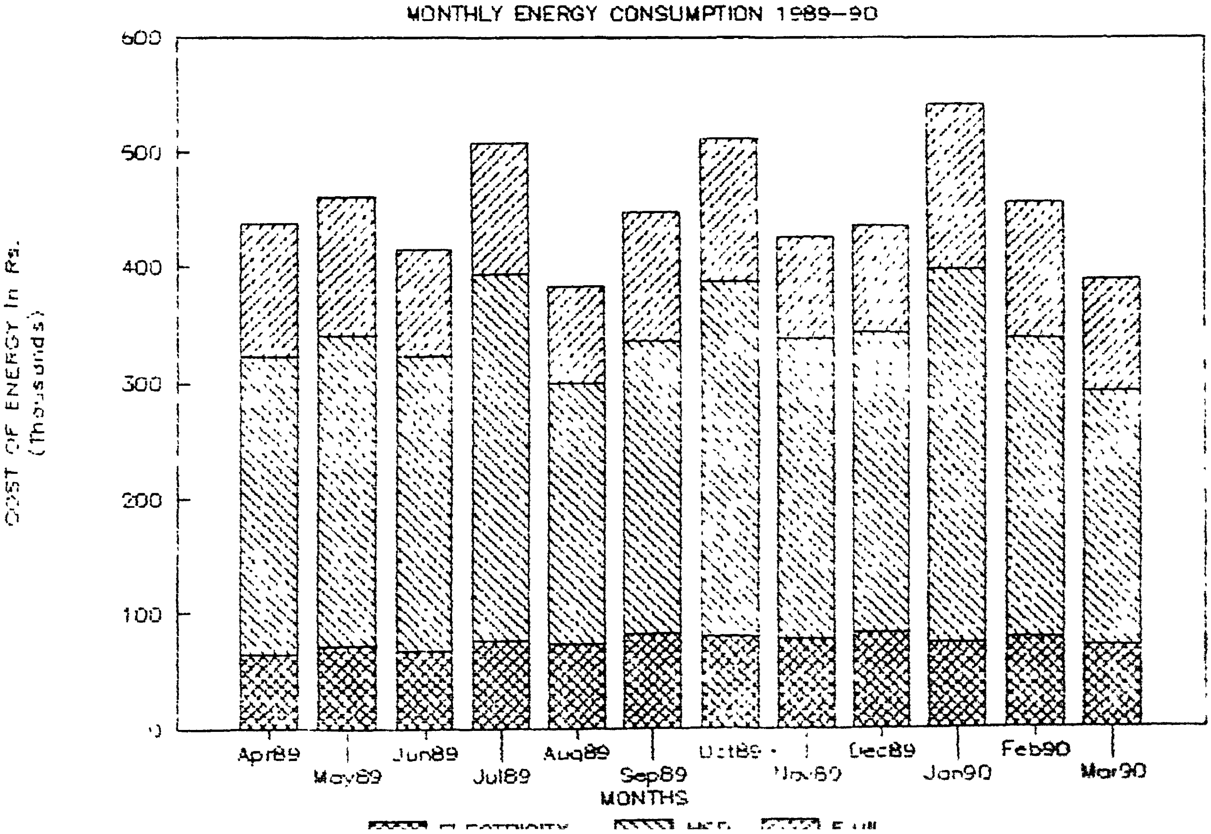
BROOKE BOND INDIA LIMITED

PRODUCTION Vs SP. ENERGY 1989-90



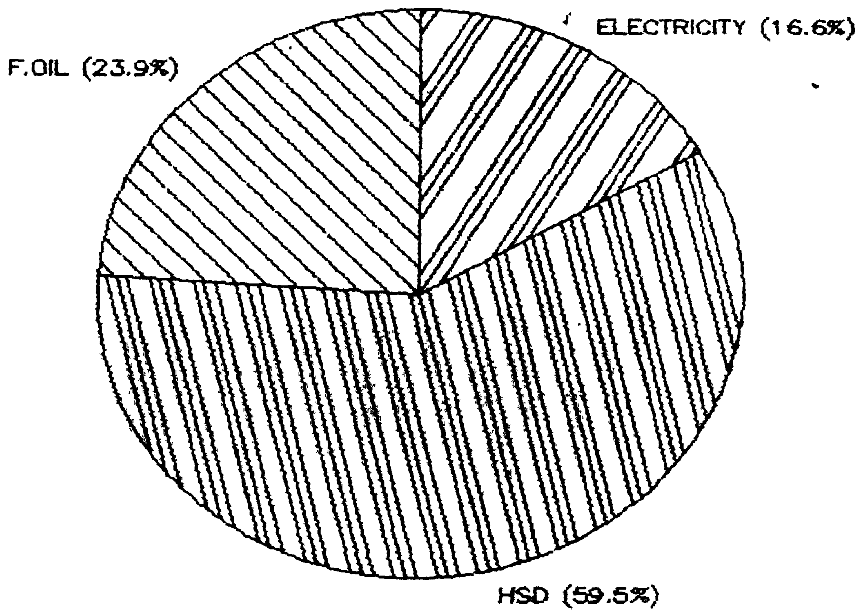
BROOKE BOND INDIA LIMITED

MONTHLY ENERGY CONSUMPTION 1989-90



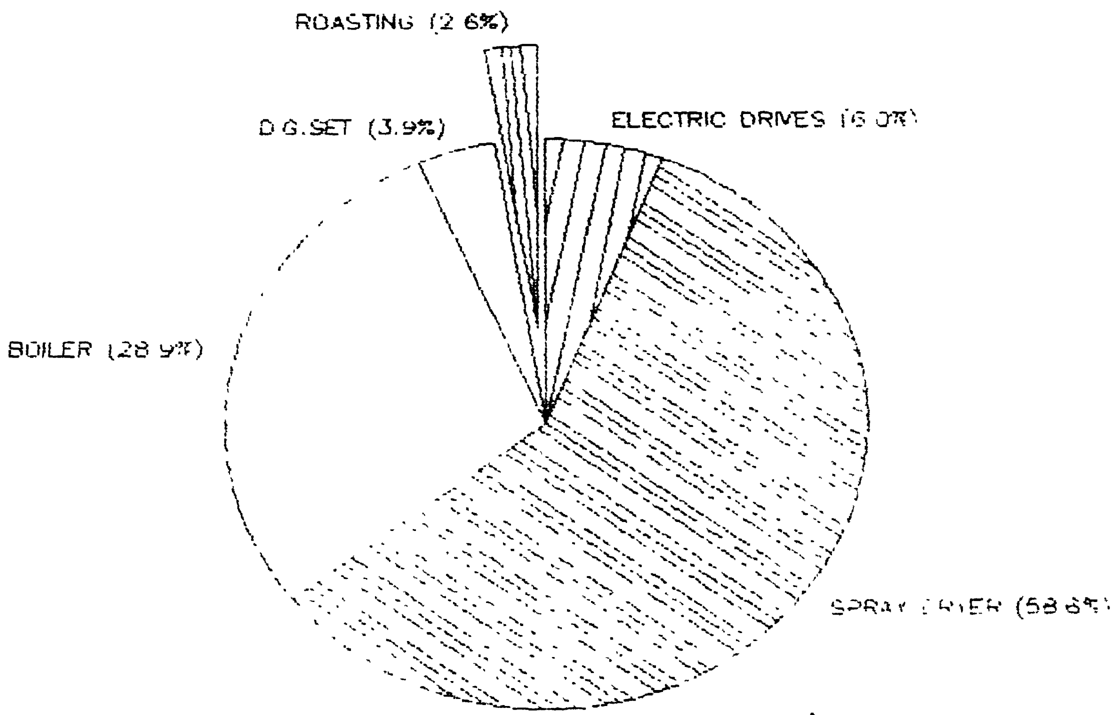
BROOKE BOND INDIA LIMITED

ENERGY DISTRIBUTION DIAGRAM 89-90

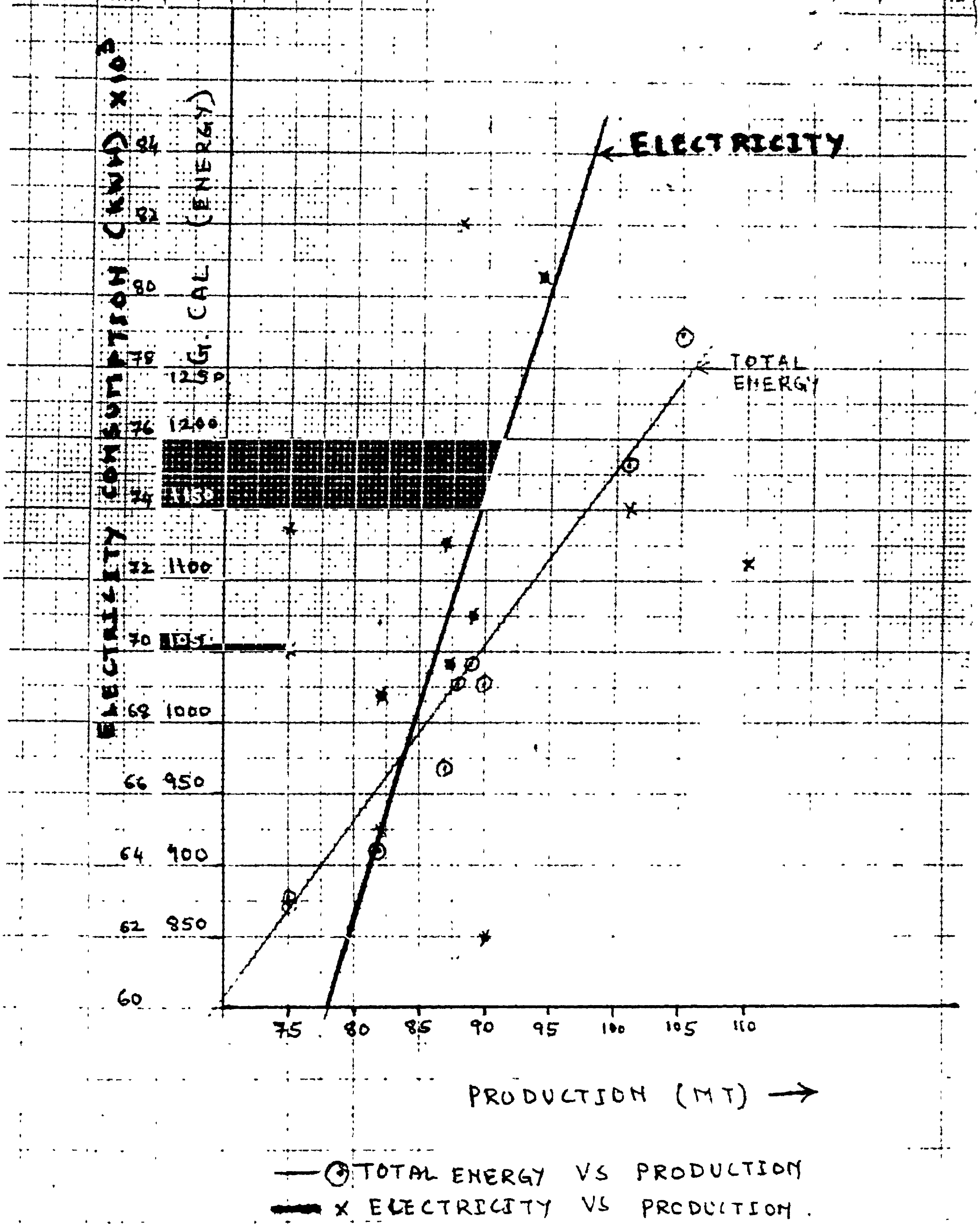


BROOKE BOND INDIA LIMITED

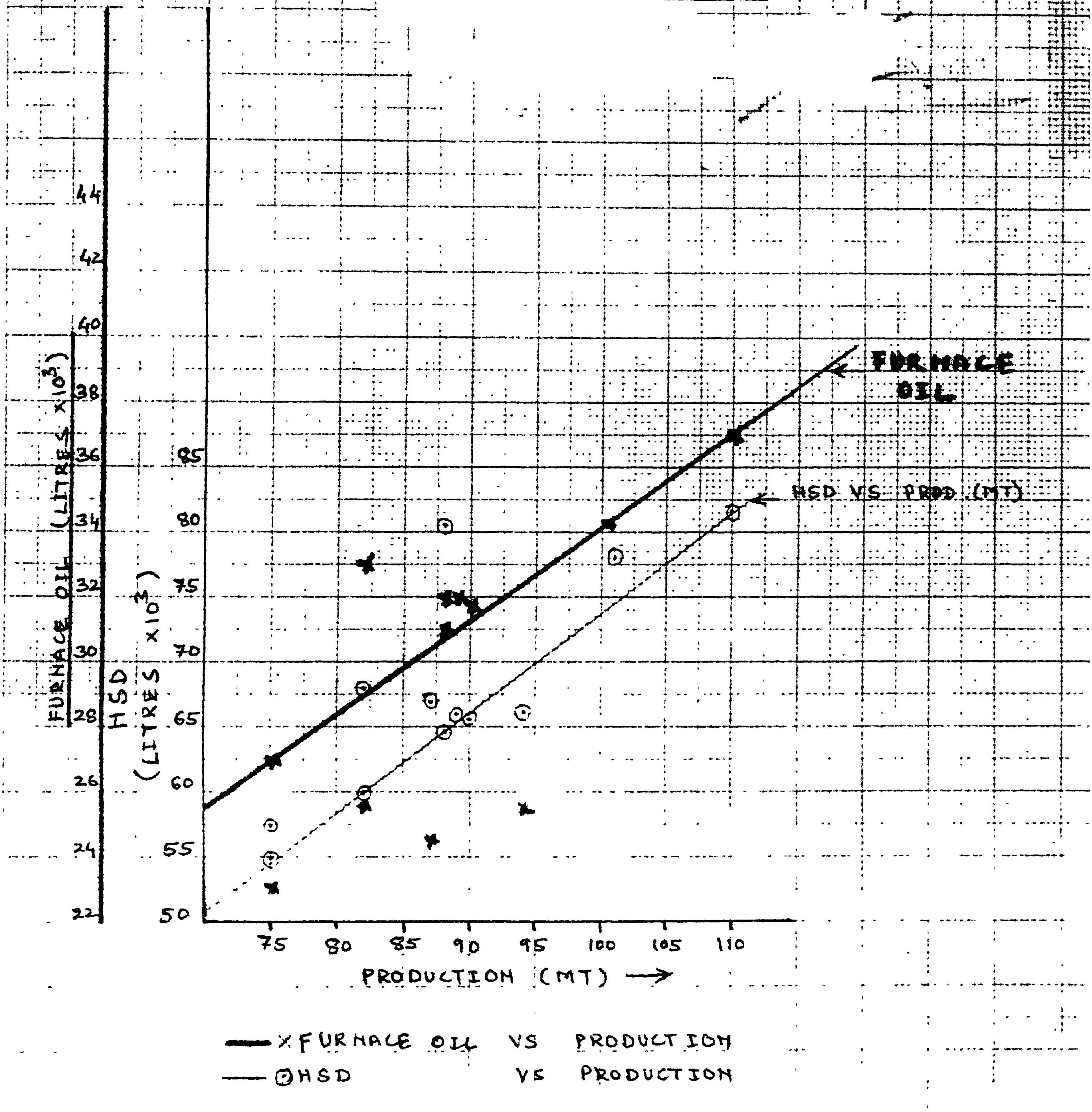
ENERGY CONSUMPTION PATTERN 89-90



ANNEXURE - VII



ANNEXURE - VIII



ANNEXURE -IX

Boiler efficiency at the maximum oil flow rate.

(HIGH FIRE RANGE)

FUEL INPUT ;

105 litres/h.

Quantity of flue gases based on analysis of the out going gases

105 x 14.7 x 1.2 = 1852.2 kg/h.

a. Heat is based on oil flow rate :

$$105 \times 10{,}000 = 10{,}50{,}000 \ \frac{\text{K.Cal}}{\text{h.}}$$

b. Heat loss in flue gases based on the analysis :

O2 = 2.0 %
Temperature = 306 Deg.C.
Total flue gas losses = 18% of the total heat input.

$$= 189{,}000 \ \frac{\text{K.Cal}}{\text{h.}}$$

c. Blow down losses (as calculated earlier)

$$= \frac{58{,}240 \text{ K.Cal}}{\text{h}}$$

= 5.55% of the heat input

d. Radiation & Convectional losses :

= (13,093 + 8972)

$$= \frac{22{,}065 \text{ K.Cal}}{\text{h.}}$$

= 2.10%

e. In complete combustion & in consistencies = 1.5%

TOTAL LOSSES = 27.75%

H of the boilers at higher fire 72.25%

Therefore Amount of Heat available to meet peak loads
$= 10{,}50{,}000 \times 0.7225$

$$= \frac{758625 \text{ K.Cal}}{\text{h.}}$$

Therefore Quantity of steam that is generated at
15 Kg/sq.cm is $\dfrac{758625}{666.6} = 1138 \dfrac{\text{Kg}}{\text{h.}}$

ANNEXURE - X

MATERIAL AND ENERGY BALANCES ON SPRAY DRYER

MOISTURE BALANCE :

1. Moisture entering in feed = Ms (Ws)1 = 700 (0.3)
   Ms = weight units per hour of dry solid = 700kg/h

   (Ws)1 = units of moisture per unit of dry solid
   30% = 2.33 Kg/ Kg. of dry solid

2. Moisture entering in hot air = Ga (H1)
   Ga = Weight units dry air per hour at temp.(Ta)1
   H1 = The absolute air humidity at the inlet

$$Ha = 18/29 \left(\frac{Pw}{(Pt - Pw)} \right)$$

   = Weight of water vapour/ Unit weight of dry air

   H1 = 0.0095 lb of H20 / Dry Air
   (from Psychrometric charts)

   (Ta)1 = 275 Deg.C

Air intake conditions in the plant = 43 RH%
(as per the measurements taken)
Dry bulb temp = 27 Deg.C
Wet bulb (from chart) = 64 Deg.F
Vapor pressure at dry bulb temp = 871.82 mm wg.(17.8 deg C)
Vapor pressure at wet bulb temp = 210.41 mm wg
1 mm WG = 0.0735 mm Hg

RH (Pressure vapor at dry bulb temp.) = Wet vapor pr.at bulb temp.

= 0.43 x 871.82 x 0.0735 = 27.55 mm Hg

or 374.88 mm wg

Therefore the Qww point or wet bulb temperature = 13.5 Deg.C

Therefore Amount of Dry = 10,505.45 Kg/h
Amount of absolute humidity = 0.0095 Kg pf H20 / Kg of Dry air

Therefore Amount of moisture in feed = Ga (H1)
= 10,505 x 0.0095
= 99.7975 kg/h

3. Moisture leaving from the dryer in the dried product
Ms (Ws)2 = 210 (0.025) = 5.25 Kg/h.
Ms = Weight of the solids (dry) per hour
(Ws)2 = Moisture content of solids out kg/kg of solid

4. Moisture leaving in the exhaust dring air : Ga (H2)
Ga = Units of dry air Kg/h
(Ha)2 = absolute air humidity at outlet
Outlet air conditions - Temperature = 105 deg.C (221 Deg.F)
RH = 5%

From psychrometric chart lb of H20/lb of dry air
= 0.0435 lb of air

Total quantity of air going out of the system will be the (Ga)1 + (G, DH) = (Ga)2
= 10505 + 2106
(Ga)2 = 12611 Kg/h

Therefore Amount of moisture having the exhaust is
(Ga)2 H2 = 12611 (0.0435)
548.57 Kg/h.

5. Stack gas velocity = x = 6.696 m/sec
Stack ID = 640 mm

Area of cross sections = 0.321699 m sq.
Volumetric flow rate = 2.1540 m cube /sec
= 7754.747 m3/h
= 7224.83 kg/h

6. Actual Quantity fresh air to spray dryer :

51 x 36 cm , 20 mesh win : of 0.125 mm

$$\frac{51 \times 2.25}{25} = 45.9 \text{ cm} \quad - \quad 0.459 \text{ m}$$

$$\frac{36 \times 2.25}{25} = 32.4 \quad - \quad 0.324 \text{ m}$$

Therefore area for flow = 0.148716 m sq.
= 0.8922 m sq.

Average velocity taken at the fresh air blower :

2.568 m/s
Therefore Volumetric flow rate = 2.568 m/s x 0.8922msq.
2.2917 m3/sec
- 8250.1688 m3/hr

Density of air at 27 deg.C is

$$(e2 = \frac{1.29 \times 273)}{300} = 1.1739 \text{ kg/m3}$$

Therefore Mass of air = 8250.1688 m3/h x 1.1739

= 9684.8732 Kg/h.

Combustion Blower air suction velocity = 17.81 m/sec.
Cross section 19 O cm, 5 mesh win, win O 0.489 mm
Therefore Area = 0.0283528 without mesh
Therefore Area with mesh = 171.418 mm O
Area with mesh = 0.02307 m sq.
Therefore volumetric flow = 0.02307m2 x 17.81 m/sec
= 0.4110235 m3/sec
= 1479.6846 m3/h x 1.1739
= 1737 kg/h
Therefore total air flow total the air preheater (a hot air generator) = 1737 kg/h + 9684.8732

= 11,421.875 Kg/h.

Now getting back to the Material Balance:

Ms (Ws)1 + Ga (H1) = Ms (Ws)2 + Gs (H2)
Therefore Ms { (Ws)1 - (Ws)2} = Ga (H2 - H1)
Therefore 210 [0.7 - (Ws)2] =

Case 1 If Ga is assumed 10,600 then dry air =10,505 kg/h

Case 2 If Ga is actual 11421.85 Kg/h as per measurements Then dry air is 11314.364 Kg./h

Enthalpy of air entring dryer :

a. Enthalpy entering dryer = Ga (Qa)1

$$
\begin{aligned}
Qa1 &= (0.24 + 0.46\ H1)\ (Ta)1 + 597\ H1 \\
&= [\ 0.24 + 0.46\ (\ 0.0095)]\ 275 + 597(0.0095) \\
&= 67.20 + 5.6715 \\
&= 72.87\ \text{K.cal/kg.} \\
Ga &= 10505\ \text{Kg/h}
\end{aligned}
$$

Therefore Enthalpy of air entering dryer = 72.87 x 10,505
= 765533.49 K.cal/h.

b. Enthalpy of feed entering dryer = Ms (Qs)1
= 210 (Qs)1

$$
\begin{aligned}
(Qs)1 &= CDS\ (DT) + (Ws)1\ CWDT \\
&= 0.4\ (40) + (2.333)\ (1)\ (40) \\
&= 109.333\ \text{K.cal/kg.}
\end{aligned}
$$

Therefore Enthalpy of feed entering dryer

= 210 (109.333)

= 22960 K.cal/h.

c. Enthalpy of exhaust drying air = Ga (Qa)2

$$
\begin{aligned}
(Ga)2 &= 10505\ \text{Kg/h} + 2106\ \text{Kg/h} = 12611\ \text{Kg/h} \\
(Qa)2 &= (0.24 + 0.46\ H2)\ (Ta)2 + 597\ H2 \\
&= [0.24 + 0.46\ (0.435)]\ (115) + 597\ (0.0435) \\
&= 55.87065\ \text{K.Cal/Kg}
\end{aligned}
$$

Therefore Enthalpy of exhaust drying a = 55.87 x 12611
= 704576.57 K.Cal/h

d. Enthalpy of dried product having dryer : Ms (Qs)2
Ms = 210

$$
\begin{aligned}
(Qs)2 &= CDS\ (DT) + (Ws)2\ CwDT \\
&= 0.4\ (40) + (0.025)\ 1\ (40) \\
&= 17.02\ \text{K.Cal/Kg}
\end{aligned}
$$

Therefore Enthalpy of dried product having dryer
= 210 x 17.025
= 3575.38 K.Cal/hr

e. QL = Heat loss from the surface of the spray dryer:
QL = UADT
A1 = 3.52989 x 2.65
= 9.3542 m2
A2 = 7.8426 x 3.920
= 30.7432 m2
A3 = 13.8354 x 9.45
= 130.9243 m2
Total area = 171.02 = A1 + A2 + A3 of the drying chamber
Average surface temperature = 60 deg.C

Therefore QL = 2 x 171.02 x (60 - 27)
= 11287.438 K.Cal/h

f. The other heat loss is in the bottom core and also heat is taken up by the air (DH)

G DH, air = 1800 m3/h. x 1.17
= 2106 Kg/h.

QDH, air in = 72.87
QDH air system = 55.87

Therefore Q1, DH = 17.00 x 2106 K.cal/h
= 35,802 K.Cal/h.

g. Bottom cone heat loss :
A = 58.09 m2
Therefore QL, cone bottom = 2 x 58.09 x (40-27)
= 1510.3774 K.Cal/h.

MOISTURE BALANCE :

(1) Moisture in feed = 490 Kg/h
(2) Moisture in air (Ga)1 = 99.7975 Kg/h.

589.7975 Kg./h

(3) Moisture in Material out = 5.25 Kg/h
(4) Moisture in (Ga)2 = 548.57

553.82 Kg/h

ENTHALPY BALANCE ;

(1)	Enthalpy of air entering dryer	=	765533.49
(2)	Enthalpy of feed entering dryer	=	22960
			788493.49

(3)	Enthalpy of exhausted dry air	=	704576.57
(4)	Enthalpy of dried solid	=	3575.38
(5)	Enthalpy of heat loss QL	=	11287.438
(6)	QL, DH	=	35802.00
(7)	QL, Cone	=	1510.00
			756751.39

EVAPORATIVE EFFICIENCY OF SPRAY DRYER

EVAPORATIVE EFFICIENCY (n evap.) is defined as the ratio of actual evaporative capacity to the capacity obtained in the ideal case of exhuasting air at saturation.

$$n\ evap = \frac{(T1 - T2)}{(T1 - T\ sat.)}\ 100$$

$$= \frac{(267 - 11.5) \times 100}{(267 - 17.8)}$$

$$= 60.99\%$$

THERMAL EFFICIENCY OF SPRAY DRYER

It is defined as the ratio.

$$\frac{\text{Heat used in evaporation}}{\text{Heat input}}$$

(a) Overall thermal efficiency (normal) is defined as the fraction of total heat supplied to the dryer used in the evaporation process.

$$\text{Normal} = \frac{(T1 - T2)}{(T1 - To)} \; 100$$

Based on actual measurements

T1 = air temperature entering the spray dryer
= 275 deg.C (267 deg.C)

TO = Atmospheric temperature = 27 deg.C

T2 = air exhaust temperature

This is based on the assumption that this process is truly adiabatic.

Case 1:

$$\text{Normal} = \frac{(275 - 115 \text{ deg.})}{(275 - 27 \text{ deg.})} \; 100$$

$$= 64.51 \%$$

$$= 65\%$$